International Journal of Mechanical and Production Engineering Research and Development (IJMPERD)
ISSN (P): 2249-6890; ISSN (E): 2249-8001
Vol. 8, Issue 4, Aug 2018, 667-676

STUDIES ON THE STRENGTH OF CARBON/EPOXY-GLASS/EPOXY HYBRID LAMINATED LAP JOINTS

BABITHA KODAVANLA[1], D. GOVARDHAN[2], GELLA SHIVA DURGA MADHAV[3] & M. SATYANARAYANA GUPTA[4]

[1,2,3]Department of Aeronautical Engineering, Institute of Aeronautical Engineering, Hyderabad, Telangana, India

[4]Department of Aeronautical Engineering, Marri Laxman Reddy Institute of Technology, Hyderabad, Telangana, India

ABSTRACT

The laminates of carbon fiber and glass fiber are made individually. The glass fibers used are of high strength. Two sheets of each are combined using epoxy resin mixed with hardener. The resin is spread evenly so that a good bond is made between the two sheets of fibers. The carbon fiber laminate, glass fiber laminates and glass-rubber combination laminations are made into small pieces and then made into a joint by lapping them at one their end using the adhesive. These composite single products which are made into a lap joint are tested in UTM. The strength of the composite product at the joint should be determined. The main objective of the composite joint is to improve structural stiffness and to obtain good strength to weight ratio.

***KEYWORDS:** Carbon Fiber, Adhesive & Weight Ratio*

Received: May 10, 2018; **Accepted:** Jun 01, 2018; **Published:** Jul 21, 2018; **Paper Id.:** IJMPERDAUG201869

Original Article

INTRODUCTION

There are in excess of 50,000 materials accessible to engineers for the outline and assembling of items for different applications. The maximum operating temperature in metals does not degrade the material the way it degrades the plastics and composites. Metals generally tend to temper and age at high temperatures, thus altering the microstructure of the metals. Due to such micro structural changes modulus and strength values generally drop. The influence of specimen thickness and influence of resin on the flexural properties evaluates the increase in thickness decreases the flexural properties such as flexural strength and flexural modulus and as the thickness increases the load carry capacity increase on the specimen. Research indicates that Flexural strength is mainly dependent on the type of resin used & thickness of laminated polymer composites [1]. Mechanical properties of the composites did not change between the pressures of 8 and 150 bars. This increase of pressure caused only a slight increase in the mechanical properties [2]. Significant change to the fiber/matrix volume fractions, density or porosity of the composites, which facilitated the comparison of the mechanical properties in composite laminates produced under different curing conditions [3]. Increasing the overlap additional layer results in significant reduction in the stress distribution throughout the joint. The suitable strength prediction of the single lap joints is essential to decrease the amount of expensive testing at the design stage. Usually designers use Hybrid single lap joints for maximum strength [4]. The holding quality of the lap joint expanded while expanding the cover length. The quality of the joint diminished while expanding the cement thickness [5]. So with above references distinctive methodologies of fiber covers have been tries out and fiber layer impact in different overlays including some new angles bringing about the extraordinary changes over the properties of the fiber covers. The examinations are for

the most part centered around the impact of thickness in different kinds of qualities for fiber covers which incorporates the effect obstruction, in-plane rigidity, high speed affect, versatile plastic nature. The changes in properties due to various thickness have been analyzed keenly and some interesting results been acquired. Those results are verified both numerically and computationally in some reports.

MATERIALS AND METHODS

Raw Materials

Composites are made of fortifying strands or fillers and matrix materials. Matrix encompasses the strands, going about as load exchanging medium and consequently ensuring those filaments against compound and ecological assault. For the present examination, following materials like epoxy gum, carbon texture, silane-treated SiC particulates are considered. Materials utilized as a part of this work are Carbon, glass and elastic texture and epoxy gum. Material properties are generally dictated by mechanical and physical tests under controlled research facility conditions or from producer or provider.

Matrix Materials

Epoxy pitch was chosen as the matrix material for the present investigation.

Table 1: The Ingredients of Matrix System

S.No	Ingredients	Trade Name	Chemical Name	Density (g/cm3)	Supplier
1	Epoxy Resin	LY 556	Diglycidal Ether Of Bisphenol A (DGEBA)	1.16	Hindustan Ciba Giegy Ltd
2	Hardener	HY 951	Triethylene Tetramine (TETA)	0.95	

Fiber Materials

Fiber materials like carbon (T300) its properties are listed below.

Table 2: Properties of Carbon Fibers

S.No	Properties	Carbon (T300)
1	Specific gravity (g/cm^3)	1.78-2.15
2	Fabric weight (g/m^2)	23gms
3	Tensile strength (MPa)	3515-6380
4	Tensile modulus (GPa)	240-410
5	Strain to failure (%)	2.9

EPOXY RESIN: Araldite LY556 is an epoxy resin used for the experiment which is suitable for the current application.

HARDNER: ARADUR HY 951 Viscosity at 25°C: 10-20 mPa*s/Specific Gravity at 25°C: 0.98 g/cm^3/Appearance: Clear fluid/Flash point: 110°C/Mix proportion: 100:10.

Properties: ARADUR HY 951 is great mechanical property, good resistance to mechanical strength, good resistance to atmosphere from climatic degradation, incredible electrical properties.

PREPARATION OF THE COMPOSITES

Preparation of Composite Test Samples

A mould of size 550 mm×550 mm× 6 mm was utilized using mild steel plates. The bi-directional carbon surface (separate crosswise over 6– 8 µm)reinforced with the LY556 Epoxy gum grid materials, included with HY951 room temperature relieving hardener and diluent DY021 (all gave by Hindustan Ciba Giegy) have been considered for board creation. Ten layers of surface were used to gain around 3 mm thick. Particulate-filled carbon surface reinforced epoxy composite was set up by hand lay-up technique, trailed by weight molding. The filler material used is SiC powder of size 5– 10 µm. The SiC filler was treated with 2% organo-open saline coupling administrator.

CARBON FABRIC AND PARTICULATE REINFORCED EPOXY COMPOSITES:

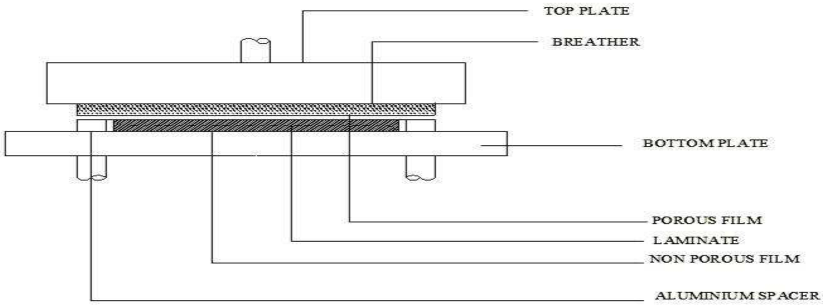

Figure 1: Hand lay-up Technique Set

Carbon texture (T-300), which is perfect with epoxy pitch, has been utilized as the fortification. The epoxy was blended with the hardener in the proportion 100:12 by weight. The become hand lay-scarce method as appeared in Figure 1 was utilized to create the composite. The stacking methodology included putting the texture one above other with the tar blend well spread between the textures. To guarantee uniform thickness of the example, a spacer of size 3 mm was utilized.

Figure 2: Compression Moulding

Table 3: Composites Selected for the Present Study

S.No	Material (Designation)	Fiber (wt.%)	Matrix (wt.%)	Filler (wt.%)	Density (g/cm3) ASTM D792
1	Carbon-epoxy (C-E)	Carbon (60±2)	Epoxy (40±2)		1.42
2	5% SiC filled carbon-epoxy (5SiC-C-E)	Carbon (60±2)	Epoxy (35±2)	SiC (5)	1.48
3	10% SiC filled carbon- epoxy (10SiC-C-E)	Carbon (60±2)	Epoxy (30±2)	SiC (10)	1.52

Figure 3: Experimental Setup for Hardness Test and Tensile test

TESTING OF SPECIMEN

Specimens for physical, mechanical and thermal tests were cut using a diamond wheel cutter as per required dimensions.

Table 4: Specimen Test for the Material

S. No	Test Performed	Specimen Size
1	Tensile	250*25*3mm
2	Resin content and density	20*20*3mm

Physical, mechanical and thermal properties of a material are the basic design data in many, if not most, applications. The physical, mechanical properties are tested as per ASTM standards. Thermal properties are tested using appropriate standard method. The execution of a building material is judged by its properties and conduct under tension, compression, shear and other static or dynamic stacking conditions in both typical and unfavorable test environments. This data is basic for choosing the best possible material in a given application and outlining a structure with the chose material.

Testing of Mechanical Properties

Mechanical properties such as tensile, compression, flexural and shear properties of the materials are tested. The equipment utilized for these tests is Universal Testing Machine, expert 2653 Floor Model with MTEST Windows; fixtures vary as per the test.

Tensile Test

Tensile properties such as tensile strength and tensile modulus of composite laminates are determined by static tension tests in accordance with ASTM D3039, used to measure the force required to break a polymer composite specimen. Tensile tests produce a stress-strain diagram, which is used to determine tensile modulus. Prepare at least five specimens with steady rectangular cross areas. Place the example in the installation by focusing it between the grip interfaces. Ensure that the whole grip length contacts the hold faces when the apparatus is shut. Traverse length is viewed as 150mm. Connect the required strain checks or extensometers to the mid-traverse, mid-width area of the example. Keeping in mind the end goal to decide the modulus of versatility, longitudinal strain ought to be estimated. Apply the heap at a consistent rate (4mm/min) until disappointment. In the event that the example breaks, record the most extreme power and strain. Encompassing temperature and dampness ought to be kept up as consistent as conceivable through the length of this test. Extreme rigidity is estimated by the greatest pressure that a material can withstand while being extended or pulled before breaking.

Tensile Fixture: The tensile strength for the material obtained are as follows.

Table 5: Dimensions for the Material

S.No	Dimensions (Width*Thickness)	Load(KN)	Tensile Strength (kN/mm2)
1	2.9X2	8.58	134
2	2.9X2	1.26	127
3	2.9X1.5	3.06	123
4	2.9X3.2	1.86	138

Flexure Test

Flexural strength is determined by ASTM D790, it measures the force required to bend a beam under three-point loading conditions. The information is regularly used to choose materials for parts that will support loads without flexing. Flexural modulus is utilized as a sign of a material's stiffness when flexed. In this test, the composite beam specimen of rectangular cross section is loaded in 3-point bending mode, a large span to thickness ratio is recommended.

- Adjust the support span length equal to 16 times of thickness of specimen, Span: Thickness =16:1.
- Place the test bar on the 3-point bend fixture and begin the test at constant rate, 2mm/min.
- End the test when the sample breaks and note the readings

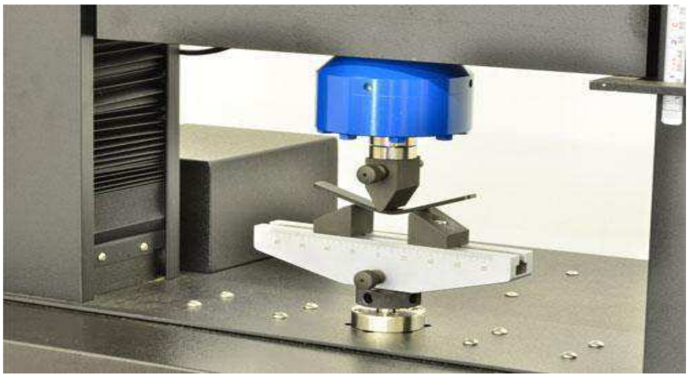

Figure 4: Three Point Bending

Specimen size considered for flexural test according to ASTM D790 is 12.7mm wide and 110mm long. Flexural strength, otherwise called modulus of rupture, bend strength, or fracture quality, is a material property, characterized as the worry in a material just before it yields in a flexure test. It is the combined impact of a material's essential malleable, compressive and shear properties. That is, the point at which a flexural stacking is connected to an example, every one of the three of the material's essential pressure states are instigated. The flexural strength represents the highest stress experienced within the material at its moment of rupture. Using a homogeneous beam theory, the flexural strength in a three-point flexural test is given by 3PfL/2bh.[2]

Table 6: Dimensions for the Material

S.No	Dimensions (Width*Thickness)	Load(KN)	Tensile Strength (kN/mm2)
1	12.81*3.09	0.458	269
2	12.91*2.86	0.447	305
3	12.94*2.82	0.447	313
4	12.77*3.14	0.497	284

Testing of Thermal Properties: Thermo-physical properties, coefficient of thermal expansion and specific heat are the couple of most critical properties of material that are required for heat exchange computations. The warm diffusivity can be utilized as a pointer of how rapidly a material will change temperature in light of the utilization of heat.

Specific Heat Capacity: Heat capacity is an important material property for composites. The DSC (differential scanning calorimeter) measures specific heat capacity by heating a sample and measuring the temperature difference between the sample and a reference. The specific heat of a material is defined as the amount of energy required to raise a unit mass of material by one unit of temperature at constant pressure.

Figure 5: DSc 8000 Double-Furnace Design

Table 7: Heat Capacity for the Material

S.No	Degrees(°C)	Joule/gm°C
1	50°C	1.16
2	100°C	1.35
3	150°C	1.57

Coefficient of Thermal expansion

Coefficient of thermal expansion is examined at different temperatures, it shows that how the size of an object changes with a change in temperature. Specifically, it measures the fractional change in size per degree change in temperature at a constant pressure. The results obtained are

Table 7: Thermal Expansion of the Material

S.No	Degrees(°C)	µm/m°C
1	100°C	2.738
2	150°C	8.108
3	250°C	19.36

RESULTS AND DISCUSSIONS

The performance of composite is known to depend on the types of fibers, matrix precursors, weave geometry (1D, 2D or 3D), nature of bonding between the fiber and the matrix (fiber-matrix interface) and processing conditions.

Resin Content and Density for the Epoxy Resin Composite Material

Table 8: *Wm*=0.29 and *Wf*= 0.71 Resin Content & Density of Epoxy

S.No	Properties	Experimental Value
1	Resin content and hardener, (by weight for 2 laminates)	100gms:10gms
2	Density of resin (g/cc)	1.16

Fiber volume fraction from equation V_f = 0.603. Theoretical density from equation (1), the mechanical and thermal properties of lap joint composite are determined at room temperature as in tables 9 to 12.

Results of Mechanical Tests on Different Types of Single Lap Joint Specimens

Table 9: Properties of Carbon-Carbon Lap Joint

S. No	Specimen	Ultimate load(kN)	Area(mm2)	Ultimate strength(kN/mm2)
1	Carbon-Carbon	8.58	45.427	0.188

Table 10: Properties of Rubber -Glass Lap Joint

S. No	Specimen	Ultimate load(kN)	Area(mm2)	Ultimate strength(kN/mm2)
1	Rubber –Glass	1.260	62.546	0.020

Table 11: Properties of Carbon -Glass Lap Joint

S. No	Specimen	Ultimate load(kN)	Area(mm2)	Ultimate strength(kN/mm2)
1	Carbon-Glass	3.060	43.344	0.070

Table 12: Properties of Glass Rubber Sandwich Lap Joint

S. No	Specimen	Ultimate load(kN)	Area(mm2)	Ultimate strength(kN/mm2)
1	Glass Rubber Sandwich	1.860	91.808	0.020

The tensile properties of different combinations of lap joint composites are good. Carbon-Carbon lap joint has high strength properties. Comparison with other glass-carbon lap joint has good bonding at the joint. The failure of the specimens is shown in figure below,

Figure 6: Tensile Tested Specimens of Single Lap Composite Joints

Stress Strain Curve

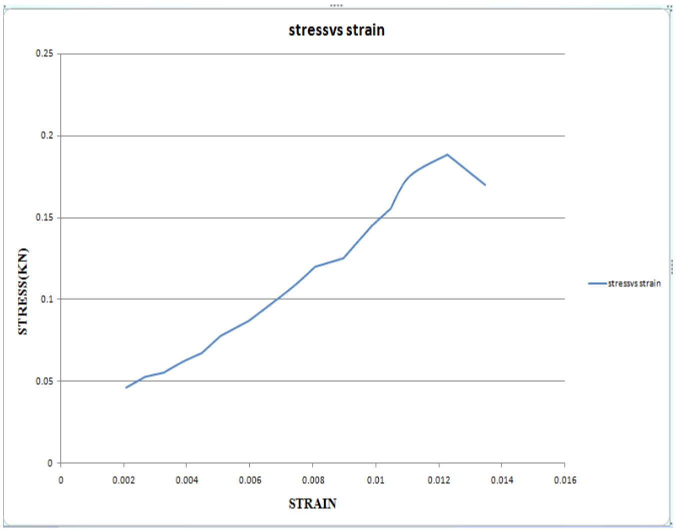

Figure 7: Carbon –Carbon

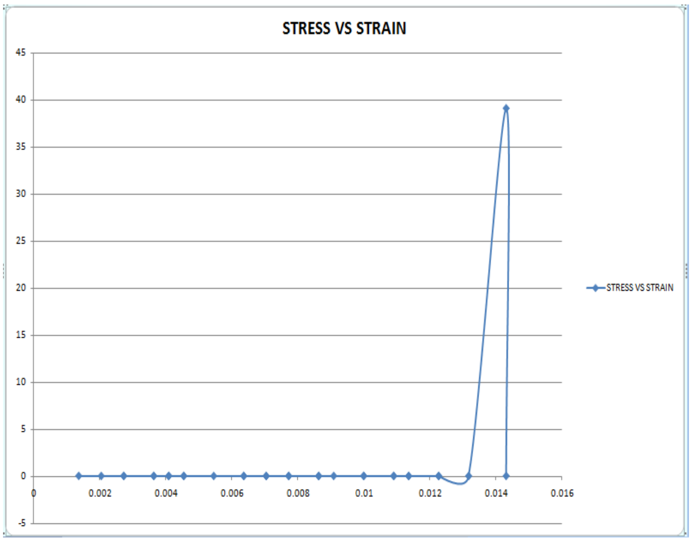

Figure 8: Rubber Glass

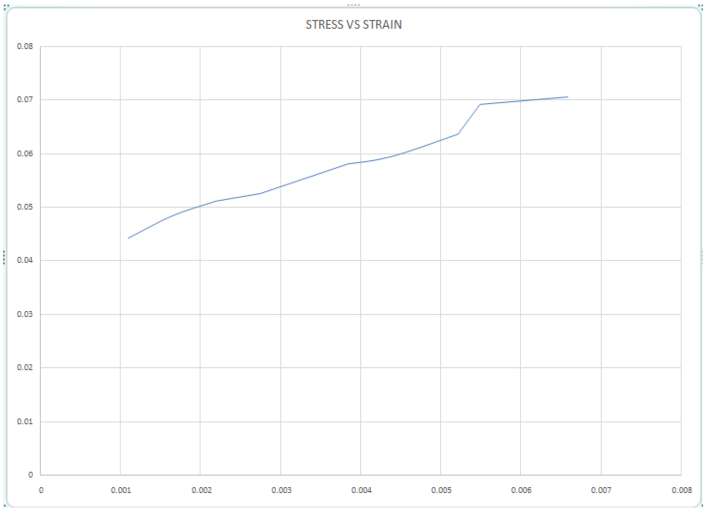

Figure 9: CARBON GLASS

CONCLUSIONS

From the results, it is observed that the hybrid joint gives better outcome in rigidity on joints under static load condition. The glass/epoxy lap joint will give a greatest peak stress. The load displacement information got from the tests were in great concurrence with investigation analysis results. The unequivocally composite single-lap joint examination strategy must have the capacity to foresee disappointment modes in GFRP composite. The appropriate quality expectation of the single lap joints is fundamental to diminish the measure of costly testing at the plan organizes. Normally originators utilize Hybrid single lap joints for most extreme strength.

Suggestions for Further Work

The further extent of this work is the need emerges to stretch out these contemplation's and results to different sorts of composite materials, by changing 176 stacking arrangement, support matrix and polymer framework utilized. This investigation can be considered as a decent methodological reference concerning what is not out of the ordinary by acoustic emanation checking of the stacking, allowing the decrements between the different damage modes. Further studies would need to be more specific to the change in frequency ranges and possibly signal magnitude of the AE for the different damage modes in lap joint with complex reinforcement architectures.

ACKNOWLEDGEMENT

Authors would like to thank Dr. L V Narasimha Prasad, Principal, IARE, and Management for their continuous research encouragement and support given for the successful completion of this work.

REFERENCES

1. *Senguttuvan, N., and J. Lillymercy. "Joint Strength Analysis of Single Lap Joint In Glass Fiber Composite Material." International Journal of Applied Engineering Research, (2015).*
2. *Deogonda, Patil, and Vijaykumar N. Chalwa. "Mechanical property of glass fiber reinforcement epoxy composites." International Journal of Scientific Engineering and Research, (2013).*
3. *Aramide, F. O., P. O. Atanda, and O. O. Olorunniwo. "Mechanical properties of a polyester fibre glass composite." International Journal of Composite Materials, (2012)*

4. *Rajmohan M, M. Balachandar, and D. Kasinathan. "Analysis of Lap Joints in Composite Materials." Indian Journal of Science and Technology (2016).*
5. *Rajmohan, M., M. Balachandar, and D. Kasinathan. "Analysis of Lap Joints in Composite Materials." Indian Journal of Science and Technology (2016).*
6. *P. Anudeep, Babitha Kodavanla, P. Srinivas Rao, "Experimental Analysis On Treated And Untreated Grass/Carbon Hybrid Composite Structures". International Journal of Applied Engineering Research And Development, (2018).*
7. *Yelluri Shwetha, Gella Shiva Durga Madhav And Dussa Govardhan, "Buckling Analysis Of Carbon Epoxy Trailing Edge Wing Rib" International Journal of Applied Engineering Research And Development, (2018).*